Industrial Pollution: Using ICT to Monitor the State of Ambient Air Quality in Lahore

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ABSTRACT
For years researchers in Pakistan are exploring ways to reduce air pollution and to improve the level of air quality. This paper describes the primary problems of air pollution specifically due to the small-factories and also it describes a solution to deal with them. Our research is specifically carried out in the city Lahore. We conducted semi-structured interviews with five factory owners belonging to various categories. These interviews were conducted to acquire the knowledge of the primary problem these factories are facing. According to our finding, unawareness remains the major problem among the factory owners. They were ignorant of how much contribution their factories are playing in making the environment unhealthy to survive. Furthermore, to address this problem we designed a device which connects to a smartphone app that gives factory owners information monitoring on air quality within their geographic locations. It equally alarms them when the air quality level is unhealthy for workers as well as for citizens. This information can therefore additionally be used by the government in an effective way.

1. INTRODUCTION
Globally, the number of air pollution-related deaths each year is estimated to be 4.2 million, with approximately 90% of these occurring in the developing world. In addition, morbidities due to air pollution include lung cancer, chronic obstructive pulmonary disease (COPD), stroke and other cardiovascular ailments [WHO].
Air pollution in developing countries has been a major issue over the past years. The key contributing factors involve the burning of fossil fuels, agricultural activities and specifically harmful emissions from factories. ICT solutions for air quality monitoring have dominated in recent years but most of the work relating to ICTs has been relatively scarce in a developing country such as Pakistan.
In this paper, we investigate the prevalent causes of air pollution by factories and its environmental impact, in the context of a sensor-based mobile application network. We conducted an exploratory research with factory owners, factory workers, local communities nearby factories and doctors in Lahore, Pakistan. We randomly sampled our subjects and tested the usability of our device and mobile application to yield qualitative findings using interviews and follow-up questions. Our observations deduced that most of our subjects did not fully comprehend the device buttons and the text-based environment for the mobile application.
These results confirm that while designing content and solutions for semi-literate audiences, we must consider their perception to understand text-based content and UI design. Giving proper attention to these abilities can help develop tailored solutions for low-literate audiences.

2. BACKGROUND AND MOTIVATION
Everyone breathes to live and breathing is dangerous nowadays. We wouldn't consume dirty water then how could we intake polluted air? Globally 4.2 million deaths occur every year as a result of exposure to ambient (outdoor) air pollution [1]. The horrific impact of air pollution is causing more than 20,000 premature deaths among adults and almost 5,000,000 cases of illness among children each year in Pakistan [2].
Explicitly, in 2018 the city of Lahore tops in the list of world's cities with worst air quality and this is primarily owing to unawareness of air standard among people [3] and lack of air quality management capabilities.
International and government bodies have highlighted the fact that air pollution has a significant danger to the environment, quality of life and the health of citizens. The air is largely being polluted by chemicals and toxic gases emitted by the factories in the atmosphere. In the recent years, many policies and works have

started in Pakistan to reduce air pollution and improve the air quality level but none of them essentially worked or accomplished its goal as it can be seen by the world air quality ranking of Lahore. In 2018 on the orders of the high court, brick kilns were shut down to improve the air quality by installing filtration plants on them but small factories are still being neglected which are unmindful of the air pollution they are causing.

Our key motivation behind this research was to provide actual insights into air quality data to the government. Therefore, the government can receive a distinct vision of the genuine stakeholders of air pollution in cities.

Furthermore, our motivation was to spread awareness among factory owners about the rising amount of air pollution and to which extent their factories are earning a part in it.

Our thought process was to chalk out such a plan that can help manufacturing plant proprietors to caution their assembly line laborers when the air quality dimension is undesirable for them.

3. RELATED WORK

Air pollution poses a serious threat to the environment specifically in a developing country like Pakistan where industrial activities are increasing rapidly [4]. Previous research works illustrate that suspended particles in the air which are formed by harmful gases like NOx, SOx and NH3 are extremely hazardous for human health. [5]. In the past, many different solutions of air quality control like reducing sulfur in fuel oil, replacing diesel fuel with CNG and restraining burning of solid waste have been proposed to curtail the impact of harmful emissions [6].

There are also projects which emphasize on creating awareness about air quality control using Information and Communication Technologies (ICT). However, only a few of them have proposed feasible solutions in this regard, particularly in the unique context of Pakistan where implementation is a key problem due to the lack of resources provided by the government. We interpret the existing literature which talks about the intervention of ICTs to mitigate air pollution and evaluates the design problems for the semi-literate audience.

- *User Experience: UI Comprehensibility*

There is a large body of researches which have acknowledged the importance of graphical interfaces and have encouraged its use. [7]. Previous ICT case studies highlight that low literate subjects preferred a graphical user environment over interfaces involving text [9]. Apart from text-free interfaces, voice call interventions and audio interpretations play a key role in the learnability of the user. [10].

- *Previously adopted techniques*

In order to provide solutions for air quality control, previous works suggest sensor-based systems which provide the basis for air pollution monitoring [11]. To provide remote sensing solutions for air quality check, methods like Lidar (light detection and ranging) and laser-induced fluorescence techniques have been advocated in the past [12]. Particulate matter and gas sensors including *Airbeam, Met One, Sensaris, and Shinyei* are fine examples of continuous monitoring applications [13]. Unfortunately, Pakistan lags the development of these devices and interfaces thus there is a need for substantial investment in these products.

4. METHODOLOGY

We used large combinations of methods for collecting data. For our research, we conducted one-on-one interviews with 5 factory owners, conducted random surveys of 10 factory workers and nearby factory community to get an insight into the qualitative perspective of our subjects about air pollution. We also conducted one-on-one interviews with 2 doctors to acquire an insight into arising diseases due to air pollution.

Interviews were semi-structured to acquire a deep understanding of the problem. The primary language used by the subjects was Urdu. Interviews were of average 20 minutes for every Subject. They were conducted at the venue which was homelike for the subjects. The venue like Factories and market shops of factory owners and Clinics of the doctors were chosen. We targeted the factories around and inside the city Lahore for our research purpose. Different categories of factories including rubber, food, paper, and plastic were taken into account so that discrete information can be collected about air pollution problem among them.

All interviews from factory owners were audio recorded with their consent and were transcripted to English for further use. Interviews with doctors were written down as they were unwilling for audio recordings. Other surveys of factory workers and nearby factory community were collected through detailed research survey.

5. FINDINGS

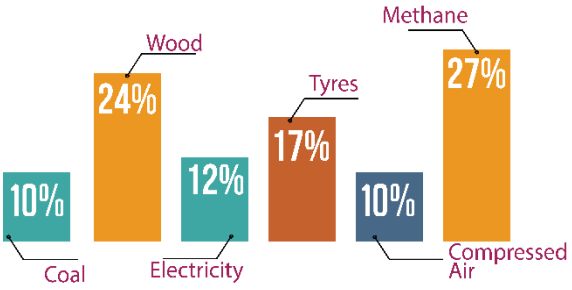
We had several qualitative findings during the interviews and through the follow-up questions.

5.1 Findings from the factory owners

Almost all factory owners whom we interviewed were literate (at least to 10th grade). Our average interview time, for them, was 20 minutes. Interviews were semi-structured with some follow-up questions to extract in-depth knowledge of the problem. Every factory owner

had a smartphone.
The key findings from our interviews were that 60% of our factory owners were unaware of the amount of air pollution their factories were causing. They were ignorant of how inhaling the unfiltered smoke is ruining their health.
We interviewed two massive factories and three small-scale factory owners, and we came to know that large factories have many filtration processes in operation but private factories do not have these filtration facilities. Especially rubber and plastic factories which are of small scale are polluting the environment to an extremely hazardous level without scarcely recognizing the fact.
Fuel used by factories was gas and electricity and when these were unavailable they used tyre, wood and also cordwood. We got insights about the fuel as quoted by one of the factory owners:
"At this place, the government has not provided us any ease. Here gas and electricity both are expensive. Prices are so high that you cannot even think of that, so to overcome this we burn wood and tyre, which are less expensive and easily available."
"Wood is available in the market this is the reason we are utilizing it. If we don't get it we don't use it.

We are provided with tyres but we are not receiving gas so we are utilizing it."
The demographics of the fuels used by the factories are shown.



Furthermore, about the government operations, we got information that it is not keeping proper check and balance of small-scale industries as they are busy keeping track of massive factories. Small factory owners are of the mind that the government should support them at small level so that they can incorporate some filtration mechanism in our factories.
During the interview, the proprietor told us they used exhaust fans and built a chimney at such a height that it is above normal human reach to save nearby community people from direct harmful smoke released by the factory. However, when we surveyed the near factory community, we came to know that in winters their rooftops are covered with black dust which is, in fact, the carbon which was released by the high chimneys of the factories.
Every factory owner was of the view that to reduce air pollution we should plant more trees but none of them had ever planted a tree themselves.
Upon asking about the air quality inside and outside the factory, 60% of the factory owners claimed it to be the same and 40% declared it to be worst inside the factory. One of the factory owners is quoted as:
"There is definitely a prominent difference. When you breathe in our factory area, you will feel like something which is burnt is getting inside you. Wood smoke and tyre smoke is going inside you. You feel like carbon is getting through breath."
Regarding, the precautionary measure about the factory workers, we extracted from the interviews that no specific measure is taken at all, normal gloves and mask are provided to them.

5.2 Findings from the factory workers

All the factory workers we surveyed belong to the average age of 18-35. None of them were literate. 80% of the factory workers we interviewed had access to a feature phone and other 20% had a smartphone. 20% of factory workers were given awareness about the air pollution in their factory and we observed that this 20% belonged to only the massive factories. This provides us with a primary finding that only large-scale factories provide awareness to their employee's others are unconcerned about it or they themselves are unaware of the problem.
60% of interviewed lived in the factories and hence from their point of view they did not find any difference in the air quality inside or outside the factories. Moreover, other 40% who lived far away from factories claimed factory area air quality to be worst.
Basic precautionary measures of gloves and masks were provided to them, according to the survey forms that were provided to the factory workers of large-scale factories. Small-scale factories, on the other hand, did not pay attention towards this which indicates their lack of awareness about the rising air pollution and its effect on people. One of the factory owners is quoted as:
"We provide them with masks and gloves only when they ask and usually they don't…"
Furthermore, we came to know from the surveys that one of the factory workers from the rubber factory had had lung cancer due to bad air quality, luckily he survived.
For the reduction of air pollution, 80% of the workers suggested to plant more trees and others gave the idea of using air friendly vehicles and to burn no crops.

6. DESIGN AND UI

Our solution consists of developing a real-time mobile application which is integrated with a sensor-based device. This section discusses the user interface design for our device and mobile application, its low prototype testing and the alterations made after testing.

6.1 Device design

The device works according to the data provided by a sensor which is embedded at a testing site to monitor the quality of air. It features an air quality meter and three LED lights representing different states including green, blue and red for good, normal and bad air quality level respectively. The meter rates the air quality according to the percentage of healthy air, below 20 for worse; from 20 to 60 normal and above 60 for good. As per our design, in a case when the red light is activated, which sets off the alarm it was the responsibility of the factory owner to regulate the factory's atmosphere and turn off the alarm by pressing the red button present on the device. Initially, it had two buttons, the first in blue color was to turn off the blue light and the second in red color was used to switch off the red light. As soon as the red button was pressed it sent out a notification message to inform the factory workers about a hazardous condition. Device design is shown below

6.2 Application UI

Our mobile application provides the current atmospheric quality and administrative rights to the factory owner. Also, it caters privilege rights to the owner to turn off the alarm from his mobile phone in case of a crisis. Initially, by using the application the user could monitor the air quality for multiple factories at different locations using GPRS and send out notification messages to workers in case an unhealthy air level is identified to inform them to take necessary precautions.

Apart from the above-mentioned features, our mobile application attributes a "My Devices" menu from which the user can access data related to multiple air quality sensors. It allows the user to acquire AQI data from various locations using a single interface. Application UI is shown below

7. Usability Testing and Results/Qualitative Observations

A preliminary usability test of our solution was tested at five different factories in the industrial and residential areas of Lahore.

7.1 Inability to understand the use of Blue light

When we tested our prototype with factory owners they did not seem to understand the use of blue light on the device. On the other hand, they easily understood the purpose of red light, as according to them it indicated a danger alert and the green light denoted a safe signal. Some of our subjects also faced difficulty in whether to press any button in case of a green light or not. One such case was when we asked the subjects that which button they should press in case of a blue light. They pressed both the buttons at once which depicted that our solution had some design limitations. We noted that our subjects were generally confused with understanding the purpose of blue colored LED and the blue button. The subjects could not perceive the use of two buttons on the device resulting in ambiguous decision making. As an alternative solution to this problem, we removed with it while keeping the red one on the device. Also we replace blue LED with yellow led which was understandable by them showing normal air conditions.

7.2 The difficulty with textual interfaces

During the prototype testing for our mobile application, we came across some subjects who were finding it hard to comprehend the textual interface of our app. Initially, we assumed that most of the factory owners would be text-literate and can easily

understand the course of action. Although, the hierarchy of our model explained useful guidelines for the ease of our user many of them requested an interface featuring more graphical icons and menus.

To solve this complication we introduced, for the device's interface an assortment of graphical icons, textual menus and an emoji section which rated the air quality with a naturally more engaging environment

As infographics have the natural tendency to appeal the human mind we derived the same analogy from our device and added an emoji section to the application interface for better compressibility of the user.

7.3 Ignoring notification messages

We observed that when the precaution message we sent at the worker's device some of them did not respond. They claimed that either they were busy in their work or could not understand the textual message forwarded to them. To rectify this problem we replaced text messages with automated voice calls and messages as they were naturally more understandable. The message sent in Urdu through voice calls was:

"السلام علیکم!
کیا آپ کو معلوم ہے کہ جس فضا میں آپ سانس لے رہے ہیں وہ انتہائی گرد آلود ہے؟
خود کو اور اپنے عزیزوں کو فضائی آلودگی کے مضر اثرات سے محفوظ رکھیں۔
چہرے پر ماسک کا استعمال لازمی بنائیں اور غیر ضروری طور پر گھر سے نکلنے سے اجتناب کریں۔
آپ کی سلامتی ہمیں عزیز ہے
"

7.4 Privilege rights for the owner in case of alarm

When the red LED was initiated the alarm set off which could only be turned off from the button on the device. The owner of the factory sometimes not present in the factory faced problems dealing with this kind of situation. To solve this problem we gave administrative rights to the factory owner on the mobile application to disable the danger alarm from any remote location.

8. CONCLUSION AND FUTURE WORK

In this paper, we described the causes of air pollution by small-scale factories in the city Lahore. As a solution, we designed a device that informs factory owners about the air quality in their factories and accordingly alarms them when air quality is bad so that through the application they can send word to their workers to adopt necessary precautionary measures.

Our work has shown that critical steps should be taken to monitor the air pollution released by small-scale factories and achieve a proper solution to deal with them. This represents an initial but necessary step in the awareness of factory owners and additionally, providing data to the government as well. We look forward to more significantly improving on it and adding the feature to inform the nearby factory community to adopt necessary precautionary measures in times of high air pollution risk.

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